# THE STRUCTURE AND CLASSIFICATION OF THE SIPHONALES

## WITH A REARRANGEMENT OF THE PRINCIPAL NORTH AMERICAN GENERA.[1]

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WITH ONE PLATE

The Siphonales consist principally of those algae in which the plant body is a coenocyte, or a row or mass of coenocytes, in some cases forming a globoid, or a simple filament, in others a branched filament, which may be free or united into a compound body. They are generally attached below by a simple or branched, usually colorless, rhizoid. The plants range in size from those which are barely visible to the naked eye up to those which are many centimeters in length. For the most part they are marine, inhabiting the shallower bodies of salt water, especially in the warmer portions of the earth.

Each coenocyte is made up of a parietal layer of protoplasm which lines the hyaline cell wall and surrounds the large vacuole. In the parietal layer are numerous small nuclei and small rounded or angled chromatophores, which may be united into a reticulum. Although many of these plants are generally without division walls, they can and do form them when the necessity for doing so arises. Thus when a filament has been injured so as to threaten the loss of its protoplasm a cross partition is quickly formed some distance

[1] This paper is in continuation of a series begun some years ago, and published in these Transactions. Systematically the groups taken up are as follows: Protophyta, Vol. XXV, pp. 89–104; Protococcoideae, Vol. XXVI, pp. 121–136; Conjugatae, Vol. XXIII, pp. 145–150; Desmidiaceae, Vol. XXII, pp. 89–96; Bacillariaceae, Vol. XXI, pp. 61–85; Phycomycetes, Vol. XXIV, pp. 27–54.

back of the point of injury. So, too, in the reproductive processes, whether asexual or sexual, partitions are formed in order to cut off the reproductive from the vegetative coenocyte.

In their reproductive processes, as far as known, the Siphonales range from the fusion of similar biciliated gametes (isogamy) to the union of a motile sperm cell (spermatozoid) with a non-motile egg (heterogamy). Zoospores, usually biciliated, are commonly present, but they are still unknown in some families.

These plants have generally been regarded as constituting a well-defined group, in which the coenocytic structure is characteristic, but within the past few years it has been found that it is by no means as sharply set off from the other green algae as was formerly supposed. In fact, it now appears probable that the coenocytic structure has been gradually attained by the formation of fewer and fewer partitions in the succession of filamentous plants.

In this paper I have made an attempt to arrange the coenocytic algae in accordance with the theory that they have been derived from multicellular filamentous algae of the Ulotrichoid type, among the Confervales, where the segments of the filament are true cells, each having a single nucleus. Near to these must be placed the Cladophoraceae, in which the segments of the filaments are more or less elongated coenocytes, each of which contains from one to many nuclei. It has been the usual practice of algologists to regard the Cladophoraceae as falling within the Confervales, to which, indeed, they are closely allied in their general structure, and still more in their reproductive processes. Recently it has been suggested that the Cladophoraceae should be united with two or three other families (Sphaeropleaceae, Valoniaceae, etc.), into an intermediate group (Siphonocladiales) between the strictly cellular and the completely coenocytic orders. This is essentially what is done by Blackman and Tansley[1] who divide the order ("Series") Siphonales into the Siphoneae (including the families Protosiphonaceae, Derbesiaceae, Caulerpaceae, Codiaceae, and Verticillatae) and the Siphonocladaceae (including the families Valoniaceae, Gomontiaceae, Cladophoraceae, and Sphaeropleaceae). Nor is this very different from the treatment of these families by Oltmanns,[2] who follows the order

[1] A Revision of the Classification of the Green Algae, by F. F. Blackman and A. G. Tansley, in *New Phytologist*, Vol. I; 1902.

[2] Morphologie und Biologie der Algen, by Friederich Oltmanns, Vol. I; 1904: Vol. II; 1905.

Ulotrichales with Siphonocladiales (including the families Cladophoraceae, Siphonocladiaceae, Valoniaceae, Dasycladaceae, and Sphaeropleaceae), leading to Siphonales (including the families Codiaceae, Bryopsidaceae, Caulerpaceae, and Vaucheriaceae). In both cases an intermediate group between the cellular filamentous algae and those which are wholly coenocytic is recognized, and in this group are placed Cladophoraceae and Sphaeropleaceae.

The arrangement in the present paper agrees with that of Blackman and Tansley, and that of Oltmanns in including Cladophoraceae and Sphaeropleaceae in the Siphonales, and placing them near the lower end of the series. I have not, however, found it possible to retain the two sub-orders, Siphoneae and Siphonocladaceae, since to do so would separate families that appear to me to be distinctly related, while at the same time it would bring together families that have only a general relationship, especially in following Oltmanns's system.

In a general way I regard the Cladophoraceae as derived from the Ulotrichaceae. The Cladophoraceae have given rise to two principal phyla, the one characterized by the retention of a distinctly filamentous structure, while in the other the coenocyte undergoes great differentiation into "root," "stem," and "leaves." The first (including Sphaeropleaceae, Phyllosiphonaceae, Codiaceae, and Vaucheriaceae) culminates vegetatively in the complex plant body of the higher Codiaceae, and sexually in the heterogamous Vaucheriaceae. The second phylum (including Valoniaceae, and its miniature, Botrydiaceae; Derbesiaceae, Bryopsidaceae, Caulerpaceae, and Dasycladaceae) finds its highest expression in the verticillate-branched, basally rooted coenocytes of the Dasycladaceae. These relations are roughly indicated by the accompanying diagram (Plate III). If we designate these phyla by their highest representatives they may be referred to as (1) the *Vaucheria* series, and (2) the *Acetabularia* series.

The evolution of Cladophoraceae from Ulotrichaceae has been almost wholly confined to the modification of the vegetative part of the plants, resulting in less segmentation of the filaments, and the consequent formation of elongated coenocytes. Asexual reproduction ("propagation") and sexual reproduction ("generation") are essentially unchanged. The family Valoniaceae is a transition group (if indeed it may not be regarded as including several

groups) in which there is much diversity of form, but one can make out at least an increasing tendency to non-septation of the filaments. In Derbesiaceae we have a beginning of that regularity of the branching of the erect filament (stalk) which is emphasized in Bryopsidaceae, reaching its culmination in the extreme regularity of the whorled branches of Dasycladaceae. Our very fragmentary knowledge of the modes of reproduction makes it impossible to speak with certainty as to the evolution of asexual and sexual organs, but it must be said that what we do know indicates that the development of these plants has been almost wholly in the structure of the plant body. It need only be said that the true position of Caulerpaceae is problematical. All that we can yet say is that it constitutes a side line which had its origin above Valoniaceae, and certainly much below Dasycladaceae. The little family Botrydiaceae is retained with its doubtfully related genera. It appears to be related to the Valoniaceae, and for the present is placed near that family. It should probably be broken up and its genera distributed elsewhere.

From Cladophoraceae to Sphaeropleaceae the development has been almost wholly confined to the sexual reproductive process. There has been such a differentiation of the gametes that instead of the free-swimming isogametes of Cladophoraceae we have small free-swimming biciliated spermatozoids, and large, rounded non-ciliated eggs, the latter not escaping from the pluriovulate gametangium. The filament of coenocytes has undergone little change from the type which is common in Cladophoraceae. In passing from Cladophoraceae to Vaucheriaceae the plant body has become almost completely non-septate, and at the same time there has been an improvement over the heterogamy of Sphaeropleaceae in the specialization of the antherid, and the reduction in the number of eggs in the gametangium from several to one. The multiciliated zoospore of *Vaucheria* may be regarded as derived from the zoospores of Cladophoraceae by a fusion of all of the biciliated zoospores of a zoosporangium into a compound, ovoid body, in which the component zoospores retain their individual cilia. The Codiaceae have developed the plant body rather than the reproductive organs, and here, after the filaments became wholly non-septate, they were aggregated into a plant body. The evolution of a more and more complex structure of the plant body is the characteristic feature in the

Codiaceae. They are related to the other families in this phylum in the tubular structure of their filaments, which are in others free and separate, while here they are interwoven into definite forms. From our meager knowledge of the zoospores and gametes it appears that they are of the type of those occurring in the Cladophoraceae, beyond which they have advanced only in reaching a differentiation in the size, but not the form, of the gametes in some genera. Not enough is known of the Phyllosiphonaceae to enable us to assign them with certainty to a place in the system. They have generally been regarded as related to the Vaucheriaceae, and on the supposition that they may have suffered degradation from a *Vaucheria*-like type they are here placed near that group.

## Order SIPHONALES

Plants coenocytic, filamentous, or saccate, often much branched, and usually basally attached by rhizoids, from septate (consisting of rows of coenocytes) to non-septate, the filaments single or aggregated into a plant body of definite form: chromatophores discoid or reticulated, parietal; propagation by: (1) The internal division of the protoplasm of a part (sporangium), or of the whole plant into spores,—in water into zoospores,—in the air into walled spores; or by (2) the contraction of definite masses of protoplasm into agamic resting-spores (aplanospores or chlamydospores); generation by the union of (1) ciliated isogametes, (2) ciliated heterogametes, or (3) spermatozoids with non-ciliated gynogametes (eggs), or of (4) antherid nuclei (non-ciliated) with eggs, in all cases producing zygotes.—Typically fresh-water and marine algae (holophytes), from which many filamentous fungi (hysterophytes) have been derived. (The latter are described in Volume XXIV of these Transactions, pp. 27 to 54.)

There are eighteen pretty well marked families, of which eleven are holophytic (algae), and seven hysterophytic (fungi). The algae only are characterized in the following key.

KEY TO THE FAMILIES.

A. Plants filamentous, septate, consisting of rows of coenocytes,
  I. Filaments simple or branched, basally attached; isogamic, *Cladophoraceae.*
  II. Filaments simple, unattached; heterogamic, *Sphaeropleaceae.*

B. Plants filamentous, irregularly branched, non-septate,
  I. Endophytic; no gametes known, *Phyllosiphonaceae.*

II. Aquatic or terrestrial,
a. Filaments more or less compacted into a large plant body; isogamic, *Codiaceae.*
b. Filaments single, free; heterogamic, *Vaucheriaceae.*
C. Plants globular, minute, non-septate, terrestrial or aquatic, basally attached by rhizoids, *Botrydiaceae.*
D. Plants non-septate when young, usually becoming septate and compound when mature; marine; zoospores biciliated, *Valoniaceae.*
E. Plants non-septate, regularly branched; marine,
I. Filaments sparingly dichotomous, erect, with basal rhizoids; zoospores multiciliated, *Derbesiaceae.*
II. Filaments pinnately branched, erect, with basal rhizoids; gametes biciliated, *Bryopsidaceae.*
III. Filaments large, branched, creeping, with lateral rhizoids, and bearing erect "leaves," *Caulerpaceae.*
IV. Filaments erect, regularly branched in whorls, with basal rhizoids, *Dasycladaceae.*

## Family Cladophoraceae

Plants filamentous, septate, simple or branched, mostly basally attached by rhizoids; coenocytes with two to many nuclei, chromatophores parietal, many, or united into a single reticulum; propagation by (1) bi- or quadri-ciliated zoospores, which are produced in undifferentiated segments, and (2) thick-walled aplanospores developing from single segments; generation by the union of biciliated isogametes.

Key to the Genera.[1]

A. Filaments unbranched,
I. Rhizoids at base of filaments,
a. Zoospores with four cilia, *Urospora.*
b. Zoospores with two cilia, *Chaetomorpha.*
II. Rhizoids lateral on the filaments, *Rhizoclonium.*
B. Filaments branched,
I. With quadriciliated zoospores, and biciliated gametes, *Cladophora.*
II. Only large, thick-walled aplanospores known, *Pithophora.*
III. Zoospores biciliated; plants minute, parasitic in shells, *Gomontia.*

1. *Urospora* Areschoug. Plant consisting of an unbranched, basally attached filament, each segment of which is short and con-

[1] In the systematic treatment of the genera of Siphonales in this paper while my plan has been to include only those known to have representatives in America, I have not hesitated to include some foreign genera where they help to a better understanding of the family, nor have I attempted to include every genus, especially where they were either not common or had little significance in the system.

tains several nuclei; zoospores ovoid, pointed, with four lateral angles, and four sub-terminal cilia; zygote spherical.—Species one, in brackish or salt waters (New England). Filaments 1 to 8 centimeters long, and 10 to 70 $\mu$ (usually 20 to 40 $\mu$) broad.

2. *Chaetomorpha* Kuetzing. Plant an unbranched, basally attached, thick-walled, filament, each segment short and containing several nuclei; zoospores ovoid, pointed, not angled, and with two sub-terminal cilia; gametes unknown.—Species many, mostly growing in brackish and salt waters, a few in fresh waters. Filaments tufted or massed, coarse (40 to 500 $\mu$ broad) and rigid.

3. *Rhizoclonium* Kuetzing. Plant an unbranched, creeping, often thick-walled, laterally attached filament, each segment short and containing two to four nuclei; zoospores and gametes unknown.—Species many, mostly growing in brackish and salt waters, a few in fresh waters. Filaments entangled, 10 to 100 $\mu$ broad.

4. *Cladophora* Kuetzing. Plant usually a branched, basally attached, thick-walled filament, each segment long and containing many nuclei; zoospores ovoid, pointed and with four sub-terminal cilia; isogametes with two cilia.—Species very many (200 to 300), common in fresh, brackish, and salt waters. Filaments usually coarse (25 to 30 $\mu$ to 400 to 500 $\mu$ broad), and forming large, floating, entangled masses ("water flannel") in strong currents of water.

5. *Pithophora* Wittrock. Plant a branched, thick-walled, basally attached filament, each segment very long and containing many nuclei; zoospores and gametes unknown; large thick-walled, ovoid or barrel-shaped aplanospores occur, intercalated or terminally on the filaments.—Species few, common in fresh waters. Filaments coarse (50 to 175 $\mu$ broad), the aplanospores larger and swollen.

6. *Gomontia* Bornet and Flahault. Plant a minute, branched filament, growing in the tissues of marine shells which they penetrate by their rhizoids; nuclei 1 to 5 in each segment; zoospores pyriform, with two cilia; gametes unknown.—Species one (New England), inhabiting the tissues of living and dead molluscous marine shells, to which they impart a greenish color.

### Family Sphaeropleaceae

Plants filamentous, septate, simple, unattached (*i. e.*, free-floating), and without rhizoids; coenocytes much elongated, and containing many small nuclei, chromatophores parietal, very numerous,

disposed in rings at frequent intervals; propagation unknown; generation by the union of biciliated spermatozoids with eggs which remain within the gametangium and become zygotes.

There is but one genus.

1. *Sphaeroplea* Agardh. Plant an unbranched, unattached filament, each segment long and containing many nuclei; zoospores unknown; spermatozoids narrowly ovoid, pointed, with two long sub-terminal cilia, formed in great numbers in segments of the filament, from which they escape by lateral pores; eggs many in each gametangium (oogone); zygotes red, germinating after a period of rest, and then forming 2 to 8 rounded, biciliated zoospores, the latter elongating into fusiform young filaments.—Species one, in fresh waters. Filaments coarse (36 to 70 $\mu$ wide), free-floating.

## Family Phyllosiphonaceae

Plants filamentous, non-septate, much-branched, living parasitically in the leaf tissues of higher plants; nuclei many; chromatophores many, small, pale green; propagation by the formation of numerous aplanospores in the branches; generation unknown.

There is but one genus.

1. *Phyllosiphon* Kuehn. With the characters of the family.—Represented by but one species, which inhabits the parenchymatous tissue of the leaves of *Arisarum vulgare* in southern Europe. It has not yet been detected in North America.

## Family Codiaceae

Plants consisting of branching, filamentous coenocytes which are interwoven into an erect or decumbent general plant body of definite form, which is rooted below; chromatophores small, parietal; propagation by biciliated zoospores formed in special branches; generation by the fusion of biciliated heterogametes. (Zoospores and gametes are known in but few of the genera.)

Key to the Genera.

A. Plant body cylindrical, spherical, or crustaceous,
  I. Not stalked, cortical cells present, *Codium.*
  II. Sometimes stalked, no cortical cells, *Avrainvillea.*
B. Plant body differentiated into stalk and crown or "leaf,"
  I. Stalk cylindrical,
    a. Crown of spreading, dichotomous, free filaments, *Penicillus.*
    b. Crown of numerous small flat "leaves" of agglutinated filaments, *Rhipocephalus.*

II. Stalk cylindrical or flattened, bearing a flat concentrically marked "leaf" of agglutinated filaments, *Udotea.*

C. Plant body consisting of a branching series of wedge-shaped segments, usually in one plane, *Halimeda.*

1. *Codium* Stackhouse. Plant body cylindrical and simple or branched, or spherical, or crustaceous, attached basally by strong rhizoids; inner filaments longitudinal, constituting the "pith," and giving rise to short, club-shaped branchlets which stand perpendicularly to the surface and constitute the "cortex"; gametes produced in certain cortical branchlets, androgametes ovoid, smaller, orange-colored, gynogametes rounder, larger, green.—Species many, in tropical and temperate seas (South Florida and Pacific Coast). Plant body from a few to many (5 to 30) centimeters long, spongy, and dark green.

2. *Avrainvillea* Decaisne. Plant body an interwoven mass of filaments, without differentiation into pith and cortex, and either without a distinct stalk, or poorly differentiated into stalk and crown; zoospores and gametes unknown.—Species few, in the warmer seas (South Florida). Plant body several centimeters high.

3. *Penicillus* Lamarck. Plant body consisting of an upright, cylindrical, basally attached, lime-encrusted stalk of interwoven filaments, bearing a crown of spreading, dichotomous, free filaments; zoospores and gametes unknown.—Species about ten, in tropical and sub-tropical seas (South Florida). Stalk from a few millimeters to several centimeters long; crown from one centimeter to several centimeters in height and width.

4. *Rhipocephalus* Kuetzing. Plant body consisting of an upright, cylindrical, basally attached, lime-encrusted stalk of interwoven filaments, bearing an elongated crown of numerous small, flat "leaves" of agglutinated filaments; zoospores and gametes unknown.—Species one, in tropical and sub-tropical seas (South Florida). Stalk 2 to 3 centimeters long; crown narrow, 6 to 8 centimeters high.

5. *Udotea* Lamouroux. Plant body consisting of an upright, cylindrical, or flattened, basally attached stalk, bearing a flat, concentrically marked "leaf" of agglutinated filaments; zoospores and gametes unknown.—Species about ten, in tropical and temperate seas (South Florida). Plants from a centimeter or so to 8 or 10 centimeters in height.

6. *Halimeda* Lamouroux. Plant body consisting of a branching series of wedge-shaped, lime-encrusted segments, composed of inter-

woven filaments; segments usually in one plane, and the basal segment firmly attached by rhizoids; zoospores biciliated, produced in rounded sporangia, marginal upon the segments.—Species many, in tropical and temperate seas (South Florida). Plants from a few to many (15 to 20 or more) centimeters in length.

### Family Vaucheriaceae

Plants filamentous, thin-walled, non-septate, and basally attached by rhizoids; nuclei minute and very numerous; chromatophores parietal, small, rounded, and very numerous; propagation by large, oval, compound zoospores, produced singly in the ends of branches; generation by the union of minute biciliated spermatozoids with large eggs which remain within the lateral gynogametangia and become thick-walled zygotes.

There is but one genus.

1. *Vaucheria* DeCandolle. Plant a bright green, branched filament, attached by a basal rhizoid; compound zoospores formed in the end segments, cut off by a partition, and composed of very many biciliated zoospores fused into an oval body, which escapes from the segment by an apical opening, swimming for a time, then coming to rest, withdrawing its cilia, covering itself with a cell wall and elongating into a new filament; antherids lateral, forming many minute, pointed spermatozoids, which have two lateral cilia; gynogametangia (oogones) lateral, each forming one large egg; zygote after a period of rest elongating into a new filament.—Species many, common in fresh and brackish waters, or on wet ground. Filaments coarse, soft-walled, usually felted ("green felt"), 5 to 20 centimeters long, and 50 to 200 $\mu$ broad.

### Family Botrydiaceae[1]

Plants minute, globular or ovoid, non-septate, terrestrial or aquatic, and basally attached by rhizoids; nuclei minute, many; chromatophores parietal, minute and rounded, or united into a reticulum;

[1] The autonomy of this family may well be doubted. As said above (page 50) it should probably be broken up and its genera distributed elsewhere. *Botrydium* may eventually be placed in the Valoniaceae, near to *Halicystis*. Whether *Protosiphon* is sufficiently distinct to be separated from *Botrydium* can only be told after the latter has been as thoroughly studied as the former. That *Codiolum* should be removed to Protococcaceae is most likely.

propagation by (1) zoospores, each with one or two cilia, (2) aplanospores which form in the rhizoids as well as in the plant above ground; generation by the union of biciliated isogametes.

KEY TO THE GENERA.

A. Rhizoids freely branched, plants terrestrial, *Botrydium.*
B. Rhizoids simple,
  I. Plants terrestrial, *Protosiphon.*
  II. Plants aquatic, marine, *Codiolum.*

1. *Botrydium* Wallroth. Plant a minute, globular, green vesicle on the surface of the ground, terminating below in a branched, colorless rhizoid which penetrates the earth; chromatophores many, minute; zoospores formed in the presence of sufficient moisture; aplanospores formed when moisture is deficient; gametes not certainly known.—Species one or two, common on moist ground. Globules 0.5 to 1 millimeter in diameter.

2. *Protosiphon* Klebs. Plant a minute, globular, green vesicle on the surface of the ground, terminating below in a simple, colorless rhizoid which penetrates the earth; chromatophores united into a reticulum; aplanospores present; isogametes uniting to form zygotes.—Species one. Globule about 0.2 millimeter in diameter.

This plant, which had been confused with *Botrydium* until separated by Klebs in 1896,[1] is now commonly regarded as quite distinct from that genus, but if we maintain the family Botrydiaceae, I see no need of transferring it to another family as is now usually done.

3. *Codiolum* A. Braun. Plant a minute, ovoid, green vesicle, terminating below in a simple, solid, colorless rhizoid; chromatophores united into a reticulum; zoospores biciliated; gametes unknown.—Species half a dozen, growing among other marine algae on stones, piles, etc. Globule from very minute to a millimeter or two in length.

This genus is very doubtfully related to the two other genera. It appears to have closer affinities with the stalked Protococcaceae, such as *Characium,* and probably should be placed there, as has been done by Oltmanns.[2]

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[1] Die Bedingungen der Fortpflanzung bei einigen Algen und Pilzen, by Georg Klebs; 1896.

[2] Morphologie und Biologie der Algen, by Friederich Oltmanns, Vol. I; 1904: Vol. II; 1905.

## Family Valoniaceae

Plants filamentous and non-septate when young, basally attached by rhizoids, usually becoming septate and branched, and often compound when mature, the segments containing many nuclei; chromatophores parietal, small, numerous, rounded or angular; propagation by (1) biciliated zoospores, and (2) aplanospores; generation unknown.—Marine plants.

"There is scarcely any family to which it is more difficult to assign distinctive general characters, owing to the much varied structure of the vegetative organs, and our ignorance of the reproductive process in most of the genera. The thallus ranges in variety from a single large cell [coenocyte] with rhizoids up to forms of complex structure with stalk and frond"—(Murray's *Introduction to the Study of Seaweeds*).

Key to the Genera.

A. Plants septate and branching at maturity,
  I. Septa at the bases of the branches,
    a. But little and irregularly branched, *Valonia.*
    b. Much and regularly branched, the branchlets uniting by rhizoids into more or less definite shapes,
      1. Branchlets united into stalked, leaf-like plants,
        *a.* Branchlets forming an open network, *Struvea.*
        *b.* Branchlets forming a solid structure, *Anodyomene.*
      2. Branchlets united into leaf-like plants, which are sessile or procumbent, and attached by central rhizoids,
        *a.* Segments (branchlets) alike, *Microdictyon.*
        *b.* Segments (branchlets) unlike, long and short, *Cystodictyon.*
      3. Branchlets uniting into irregular masses, *Boodlea.*
  II. No septa at the bases of the branches,
    a. Plant filamentous or columnar, *Siphonocladus.*
    b. Plant a non-septated stalk, bearing a head of interwoven branches, *Chamaedoris.*
B. Plants septate, unbranched, consisting of a layer of hexagonal cells united by haptera, *Dictyosphaeria.*
C. Plants strictly non-septate,
  I. Globoid, attached by a disk, *Halicystis.*
  II. Cylindrical, much branched, *Apjohnia.*

1. *Valonia* Ginnani. Plant irregularly tubular or vesicular, little and irregularly branched, with a septum at the base of each branch; zoospores biciliated, produced in ordinary cells; aplanospores present.—Species many, marine, in the warmer seas (South Florida?). Plants from a few millimeters to several centimeters in height.

2. *Struvea* Sonder. Plant consisting of a non-septate, erect stalk, which bears a leaf-like structure composed of the regularly pinnate branchlets which have united into an open network; rhizoids basal, well developed; zoospores unknown.—Species few, marine, in the warmer seas (South Florida?). Plants tufted, from a few millimeters to one or two decimeters in height.

3. *Anodyomene* Lamouroux. Plant consisting of a short, erect, compound stalk, which bears a leaf-like structure composed of repeatedly radiate branchlets which have united into a solid tissue; zoospores not certainly known.—Species few, marine (South Florida). Plants a few centimeters high.

4. *Microdictyon* Decaisne. Plant a leaf-like, procumbent structure composed of irregularly placed similar branchlets, which have united into an open network; rhizoids short, central; zoospores not certainly known.—Species few, marine (Mediterranean Sea to Philippine Islands). Plants several to many (30) centimeters in diameter, each forming a filmy, expanded network on the surface of rocks or other algae.

5. *Cystodictyon* Gray. Plant a sessile or procumbent leaf-like structure composed of irregularly placed, dissimilar (long and short) branchlets, which have united into an open network; rhizoids short, central; zoospores unknown.—Species one or two, marine (Chinese coast). Plants one to several centimeters in diameter.

6. *Boodlea* Murray and DeToni. Plant an irregular spongy mass composed of irregularly placed branchlets which have united into an open network; rhizoids apparently wanting; zoospores unknown.—Species one, marine (Japanese coast). Plants small.

7. *Siphonocladus* Schmitz. Plant at first non-septate, later abundantly septate, erect or prostrate, sometimes saccate, often much-branched; rhizoids basal, well developed; zoospores biciliated.—Species few, marine (South Florida). Plants usually one to several centimeters high.

8. *Chamaedoris* Montagne. Plant consisting of a non-septate, erect, constricted and corrugated stalk, bearing a bushy-spreading or cup-like head of interwoven branches; rhizoids at base of stalk; zoospores unknown.—Species one, marine (South Florida). Plants tufted, 3 to 5 centimeters high.

9. *Dictyosphaeria* Decaisne. Plant at first a hollow, cellular globule with a basal rhizoid, at length bursting into an expanded

layer of hexagonal cells united by haptera; zoospores unknown.—Species few, marine (South Florida). Plants when mature irregular in outline and several centimeters in diameter.

10. *Halicystis* Areschoug. Plant non-septate, spheroidal, attached by a stalk with a disk (rhizoid) below; zoospores unknown.—Species one, marine (European). Plants 4 to 8 millimeters high.

11. *Apjohnia* Harvey. Plant non-septate throughout, erect, cylindrical, repeatedly branched into a dendroid structure, with constrictions at the points of origin of the branches; rhizoids basal, well developed; zoospores unknown.—Species one, marine (Australia). Plants tufted, 8 to 15 centimeters high.

### Family Derbesiaceae

Plants consisting of simple or sparingly dichotomous, erect, coenocytic filaments, which are rooted below; chromatophores small, oval, numerous; propagation by the production of zoospores in short, rounded, lateral branches, each zoospore broadly ovoid, with a crown of many cilia; generation unknown.

There is but one genus.

1. *Derbesia* Solier. Plant an erect filament, usually little branched, bearing rounded lateral zoosporangia; zoospores with a crown of cilia.—Species few, marine (South Florida). Plants tufted, coarse, 1 to 5 centimeters high.

### Family Bryopsidaceae

Plants consisting of erect, coenocytic stems, rooted below, and regularly pinnate-branched above, the branches again sub-divided into branchlets, the whole plant non-septate; chromatophores small, oval or elliptical, parietal; propagation unknown; generation by the union of biciliated heterogametes which are produced in lateral branchlets.

There is but one genus.

1. *Bryopsis* Lamouroux. Plant erect, very regularly pinnate-branched, and attached below by well-developed rhizoids; zoospores unknown; androgametes smaller, elongated, pointed, orange-colored, biciliated; gynogametes larger, thicker, pointed, green, biciliated.—Species many, marine (New York to Florida). Plants tufted or single, from 2 to 15 centimeters high.

## Family Caulerpaceae

Plants consisting of long, creeping, coenocytic, laterally rooted stems which bear erect, simple, pinnate or variously lobed leaf-like branches ("leaves"), the whole structure being non-septate, but supplied with numerous "cross-beams" which prevent the collapsing of the large coenocytes; chromatophores small, parietal; propagation and generation wholly unknown.

There is but one genus.

1. *Caulerpa* Lamouroux. Plant a creeping rhizome-like stem which is rooted at frequent intervals, and bears erect "leaves" which may be simple or variously branched; neither zoospores nor gametes are known, and it is supposed that new plants are produced by fragmentation.—Species many (75 to 80), mostly in tropical and sub-tropical seas (South Florida). Rhizomes from a few to many centimeters long; "leaves" from small (a centimeter) to many centimeters high, and from simple, oblong, flat structures to those of much complexity and beauty of pattern.

## Family Dasycladaceae

Plants consisting of erect, filamentous coenocytes, which are basally attached by rhizoids, and bearing a succession of whorled branches; chromatophores many, small, parietal; propagation unknown; generation by the union of biciliated isogametes which may form directly in gametangia, or aplanospores may form and give rise to gametes.

Key to the Genera.

A. Stem mostly covered with whorls of persistent branches,
  I. Whorls naked, free, not encrusted with lime, *Botryophora.*
  II. Whorls united into a cortex, which is encrusted with lime,
    a. Stem simple, unbranched, *Neomeris.*
    b. Stem repeatedly dichotomous in one plane, *Cymopolia.*
B. Lower portion of stem naked, upper part bearing one or more whorls of deciduous branches, *Acetabularia.*

1. *Botryophora* J. G. Agardh. Plant a simple, erect stem bearing very many whorls of mostly persistent free branches which are again branched dichotomously or trichotomously, not united into a cortex, nor encrusted with lime; zoospores unknown; gametes not yet observed, aplanospores present.—Species one, in sub-tropical seas (South Florida). Plants tufted, 2 to 6 centimeters high.

2. *Neomeris* Lamouroux. Plant a simple, erect stem, bearing upon its whole length close whorls of dichotomous branches which are united into a cortex, and encrusted with lime; zoospores and gametes unknown; gametangia present.—Species few, in tropical and sub-tropical seas (South Florida). Plants tufted, 2 to 3 centimeters high.

3. *Cymopolia* Lamouroux. Plant consisting of a main stem which is repeatedly dichotomous in one plane, and covered for its whole length with close whorls of dichotomous or trichotomous branches which are united into a cortex and encrusted with lime; zoospores and gametes unknown; gametangia present.—Species two, in tropical and sub-tropical seas (South Florida). Plants tufted, 6 to 10 centimeters high.

4. *Acetabularia* Lamouroux. Plant consisting of a naked stem which bears one or more whorls of deciduous branches on its upper portion; fertile branches simple and agglutinated into a disk; zoospores unknown; gametes biciliated, formed in aplanospores which are produced in the disk branches.—Species few, in tropical and sub-tropical seas (South Florida). Plants scattered or tufted, 5 to 12 centimeters high, bearing disks from 0.4 centimeter to 2 centimeters in diameter, the whole plant encrusted with lime.

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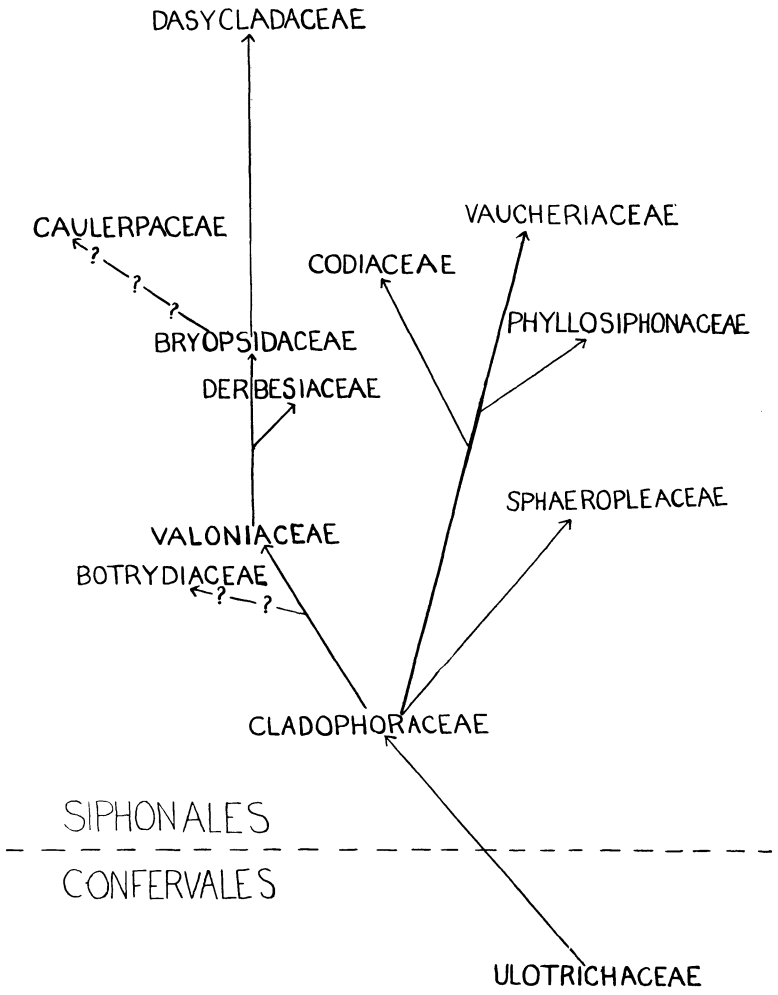
## EXPLANATION OF PLATE

### Plate III

CHART TO SHOW THE MUTUAL RELATIONSHIPS OF THE FAMILIES OF SIPHONALES.

The dotted line below marks the boundary between the Confervales and Siphonales.

PLATE III


DASYCLADACEAE
CAULERPACEAE
? ? ?
BRYOPSIDACEAE
DERBESIACEAE
VALONIACEAE
BOTRYDIACEAE
? ?
VAUCHERIACEAE
CODIACEAE
PHYLLOSIPHONACEAE
SPHAEROPLEACEAE
CLADOPHORACEAE
SIPHONALES
CONFERVALES
ULOTRICHACEAE